

CLAIMS

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. A battery charging apparatus which charges a second battery, comprising:

a voltage detecting circuit for detecting a battery voltage of said second battery and for outputting a signal in response to said detected battery voltage;

a current detecting circuit for detecting a battery current supplied to said second battery and for outputting a signal in response to said detected battery current;

a charging circuit for controlling a current supply to said second battery to charge said second battery such that said battery voltage detected by said voltage detecting circuit becomes substantially equal to a first pre-set battery voltage in response to a first input control signal applied thereto and also such that a charging current detected by the current detecting circuit becomes substantially equal to a charging current predetermined in response to a second input control signal applied thereto; and

a charge control circuit that instructs said charging circuit by sending said first and said second input control signals applied to said charging circuit to set said battery voltage and said charging current in response to a voltage indicated by said signal outputs from said voltage detecting circuit and said current detecting circuits respectively.

2. The battery charging apparatus as defined in Claim 1, wherein the charge control circuit instructs the charging circuit to perform a constant current charging in which a charging is executed to flow a first constant current to the second battery and subsequently another charging is executed to flow a second constant current greater than the first constant current to the second battery when the battery voltage of the second battery is smaller than a second pre-set voltage, and instructs the charging circuit to perform pulse charging, in which flowing current to said second battery and pausing current flow to said second battery are alternately performed at intervals of a pre-determined time period.

3. The battery charging apparatus as defined in Claim 2, wherein the charge control circuit instructs the charging circuit to control the charging current flowing to the second battery such that the battery voltage becomes substantially equal to a third constant voltage during the constant current charging during the pulse charging and also such that the battery voltage becomes substantially equal to the first constant voltage smaller than the third constant voltage during the pausing in the pulse charging.

4. The battery charging apparatus as defined in Claim 3, wherein the charge control circuit instructs the charging circuit to perform the constant current charging to supply the second constant current to the second battery when the battery voltage becomes substantially equal to a third pre-set voltage greater than the second pre-set voltage and also to perform the constant voltage charging to control the charging current such that the battery voltage becomes substantially equal to the third constant voltage when the battery voltage becomes substantially equal to a fourth pre-set voltage greater than the third pre-set voltage.

5. The battery charging apparatus as defined in Claim 3, wherein the charge control circuit instructs the charging circuit to control the charging current flowing through the second battery such that the battery voltage becomes substantially equal to the third constant voltage during the constant current charging before the pulse charging is executed.

6. The battery charging apparatus as defined in Claim 3, wherein the charge control circuit instructs the charging circuit to control the charging current flowing through the second battery such that the battery voltage becomes substantially equal to the first constant voltage when the battery voltage is smaller than the first pre-set voltage which is smaller than the second pre-set voltage and also such that the battery voltage becomes substantially equal to the second constant voltage which is less than the third constant voltage and greater than the first constant voltage, during the constant current charging before the pulse charging is executed.

7. The battery charging apparatus as defined in Claim 5, wherein the charging circuit further comprises:

a constant voltage generating circuit that generates first, second, and third constant voltages;

a voltage switching circuit that selects and outputs one of the first and third constant voltages output from the constant voltage generating circuit in accordance with the control signals from the charge control circuit;

a control transistor that outputs a current to the second battery in response to a control signal input thereto; and

a control circuit that controls the control transistor such that the battery voltage represented by a signal output from the voltage detecting circuit becomes substantially equal to a voltage represented by a signal output from the voltage switching circuit and that the charging current represented by a signal output from the current detecting circuit becomes substantially equal to a constant current represented by a signal output from the signal switching circuit.

8. The battery charging apparatus as defined in Claim 6, wherein the charging circuit further comprises:

a constant voltage generating circuit that generates first, second, and third constant voltages;

a voltage switching circuit that selects and outputs one of the first and third constant voltages output from the constant voltage generating circuit in accordance with the control signals from the charge control circuit;

a control transistor that outputs a current to the second battery in response to a control signal input thereto; and

a control circuit that controls the control transistor such that the battery voltage represented by a signal output from the voltage detecting circuit becomes

substantially equal to a voltage represented by a signal output from the voltage switching circuit and that the charging current represented by a signal output from the current detecting circuit becomes substantially equal to a constant current represented by a signal output from the signal switching circuit.

9. The battery charging apparatus as defined in Claim 2, further comprising a charge-end detecting circuit that determines an event that indicates a charging is completed relative to the second battery and outputs a predetermined signal when the charging current detected by the current detecting circuit becomes lower than the first constant current,

and wherein the charge control circuit causes the charging circuit to stop the charging upon receiving the signal indicative of a charge end output from the charge-end detecting circuit.

10. The battery charging apparatus as defined in Claim 3, wherein the first constant voltage is a voltage greater than an over discharge voltage of the second battery and the third constant voltage is a voltage substantially equal to a full charge voltage of the second battery.

11. The battery charging apparatus as defined in Claim 7, wherein the current detecting circuit comprises:

a resistor through which the charge current to be supplied to the second battery flows; and

a current detector that detects the charge current based on a voltage across the resistor and outputs a signal in response to the detected charge current,

wherein the voltage detecting circuit, the current detector of the current detecting circuit, the charge control circuit, a charge-end detecting circuit, and several components of the charging circuit including a constant voltage generating circuit, a voltage switching circuit, a constant current reference signal generating circuit, a signal switching circuit, and a control circuit are integrated into a signal integrated circuit chip.

12. The battery charging apparatus as defined in Claim 8, wherein the current detecting circuit comprises:

a resistor through which the charge current to be supplied to the second battery flows; and

a current detector that detects the charge current based on a voltage across the resistor and outputs a signal in response to the detected charge current,

wherein the voltage detecting circuit, the current detector of the current detecting circuit, the charge control circuit, a charge-end detecting circuit, and several components of the charging circuit including a constant voltage generating circuit, a voltage switching circuit, a constant current reference signal generating circuit, a signal switching circuit, and a control circuit are integrated into a signal integrated circuit chip.

13. The battery charging apparatus as defined in Claim 1, wherein the second battery is a nonaqueous second battery.

14. The battery charging apparatus as defined in Claim 1, wherein the second battery is a lithium ion battery.

15. A charging method for a second battery, comprising the steps of:

first performing a first constant current charging by supplying a first constant current to the second battery when a battery voltage of the second battery is smaller than a first pre-set voltage;

second performing a second constant current charging by supplying a second constant current greater than the first constant current to the second battery when the battery voltage of the second battery is greater than the first pre-set voltage; and

operating a pulse charging when the battery voltage of the second battery becomes equal to or greater than a second pre-set voltage greater than the first pre-set voltage by alternately carrying out at intervals of a predetermined time period, a constant

current charging in which the second constant current is supplied to the second battery and a pausing in which the supply of the constant current charging is stopped.

16. The charging method as defined in Claim 15, wherein the operating step comprises a step of controlling the charge current to the second battery such that the battery voltage of the second battery becomes substantially equal to a third constant voltage during the constant current charging of the pulse charging and such that the battery voltage of the second battery becomes substantially equal to a first constant voltage smaller than the third constant voltage during the pausing of the pulse charging.

17. The charging method as defined in Claim 16, further comprising steps of first executing a constant current charging in which the constant current charging with the second constant current is performed to the second battery when the battery voltage of the second battery becomes substantially equal to the third pre-set voltage equal to or greater than the second pre-set voltage and second executing a constant voltage charging in which the charging current is controlled such that the battery voltage of the second battery becomes substantially equal to the third constant voltage when the battery voltage of the second battery becomes substantially equal a fourth pre-set voltage equal to or greater than the third pre-set voltage.

18. The charging method as defined in Claim 16, wherein the charging current to the second battery is controlled such that the battery voltage of the second battery becomes substantially equal to the third constant voltage during the first and second constant current charging.

19. The charging method as defined in Claim 16, wherein the charging current to the second battery is controlled such that the battery voltage of the second battery becomes substantially equal to the first constant voltage when the battery voltage of the second battery is smaller than the first pre-set voltage during the first constant current charging and such that the battery voltage of the second battery becomes substantially equal to the second constant voltage smaller than the third constant voltage and greater than the first constant voltage during the first constant current charging.

20. The charging method as defined in Claim 15, further comprising steps of determining that the charging is completed when the charging current to the second battery becomes substantially equal to a predetermined current value smaller than the first constant current and subsequently terminating the charging to the second battery.

21. The charging method as defined in Claim 15, wherein the second battery is a nonaqueous second battery.

22. The charging method as defined in Claim 15, wherein the second battery is a lithium ion battery.